Chapter 1

The Evolutionary Dynamics of the Mixe Language

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Abstract

Mexico has been characterized by its great linguistic diversity concentrating 364 native linguistic variants from 11 native linguistic families. Unfortunately, the risk of disappearing of Mexican indigenous languages represents a problem for Mexican culture since they are precisely the medium through which cultural knowledge is transmitted. The risk of disappearing is reflected on a small number of native speakers and their geographical dispersion, the prevalence of adult speakers, and the tendency to abandon transmission strategies to youngest generations. The aim of this chapter is to analyze the impact of idiolect mutations on the evolutionary dynamics of the linguistic group Mixe in Camotlán, San Sebastian, Puxmetacán, Mazatlan, and Coatlán communities. First, we develop a conceptual model of the linguistic group Mixe as complex adaptive system, followed by the implementation of an agent-based simulation model in NetLogo, and finally, we analyze the evolutionary dynamics of the Mixe language, depending on the mutation rate of the idiolects. From the simulation analysis, we observe that when the mutation rate in idiolects is equal to zero, the Mixe language becomes homogenous. On the contrary, when the rate of mutations is equal to 100, a large number of language variants are generated and the risk of disappearing increases for Mixe language.

Keywords: Mixe language, modeling and simulation, complex systems, agent-based modeling

1. Introduction

At the global level, languages have been recognized by the UNESCO as instruments for the preservation and development of the tangible and intangible heritage of the world. All efforts focused on promoting the dissemination of native languages have not only emphasized linguistic diversity and multilingual-multicultural education but have also led to greater awareness of linguistic and cultural traditions throughout the world and have inspired solidarity with indigenous people, based on the understanding, tolerance, and dialogue [1].

It is widely accepted that linguistic diversity at global level is concentrated in nine countries, which have almost 3500 native languages. These countries are Papua, New Guinea, Indonesia, Nigeria, India, Cameron, Australia, Mexico, Zaire, and Brazil [2].

In 2008, the National Institute of Indigenous Languages (INALI) issued a document called Catalogue of National Indigenous Languages [3]. In this catalog, the INALI recognized that in Mexico, there are 68 native linguistic groups derived from 11 native language families, generating 364 native variants. The 11 native linguistic families recognized by the INALI are the following: Álgica, Uto-Aztecan, Yuman Cochimí-Seri, Oto-Mangue, Maya, Totonac-tepechua, Tarasca, Mixe-Zoque, Chontal, and Huave Oaxaca.

On the one hand, the Mexican Federal States of Oaxaca, Veracruz, Sonora, Michoacan, and Hidalgo have the concentration of the greatest number of native linguistic families (see **Figure 1**).

On the other hand, considering the criterion of historical settlements, the Federal States that concentrate the largest number of native linguistic groups are Chiapas and Oaxaca, followed by Campeche, Quintana Roo, and Veracruz.

From the linguistic perspective, native languages are determined mainly by human cognitive abilities such as the processes of perception, attention, learning, categorization, flowcharting, and memory [5]. Also, native languages are useful for sociocultural interactions of the villagers. In this direction, the capabilities of native languages depend on the role of speakers in socioeconomic, political, cultural, and environmental contexts. As Ref. [6] points out, native languages play a fundamental role in society and culture as they provide the central means through which cultural knowledge is transmitted.

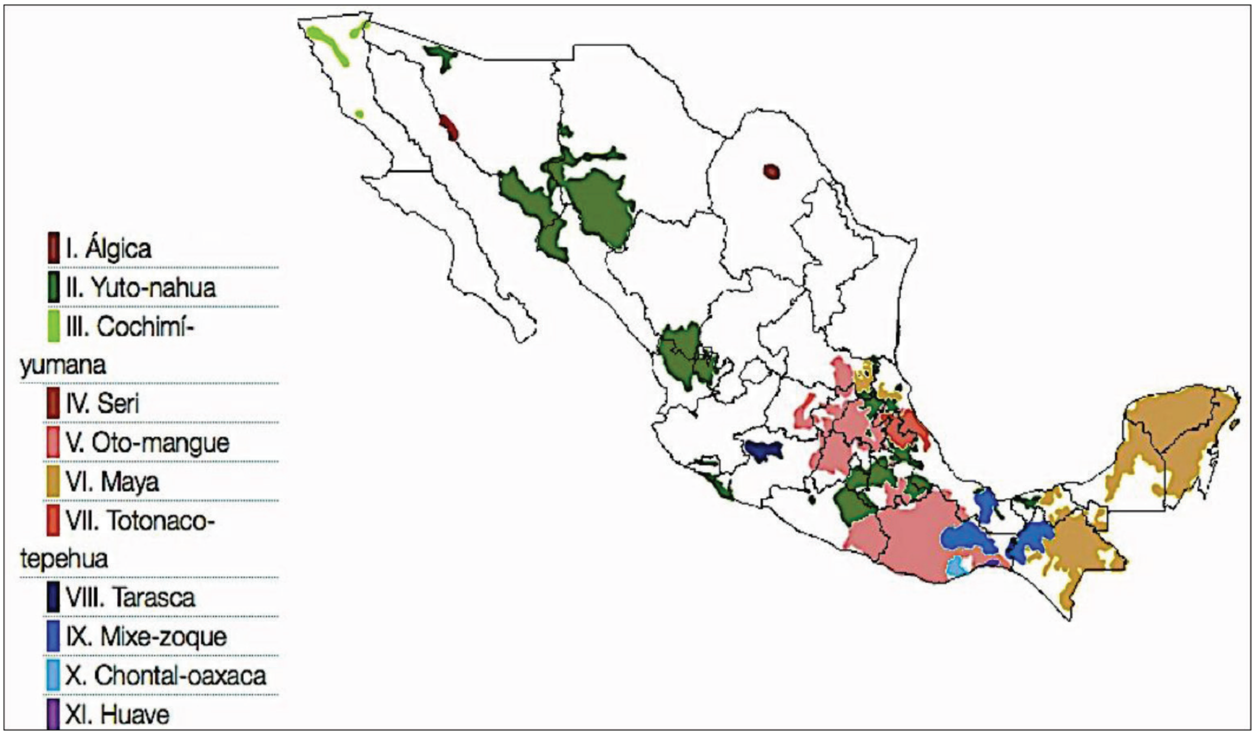

Figure 1. Geographical distribution of the eleven native linguistic families in Mexico based on Ref. [4].

From the systemic perspective, native languages can be conceptualized as complex systems with emergent properties that arise from the social interaction among their speakers [7]. The communicative interactions over time among native speakers and communities have produced changes in native languages such as coadaptation, reorganization, and development, which enable the communication process optimization among speakers, both at individual and community level. For instance, at individual level, native speakers are able to generate their own idiolect, from their experience with their environment/context. While at community level, the native language is considered and emergent property that arises from the complex dynamic interactions among idiolects of speakers [8].

The problem that currently native languages are facing in Mexico is the high risk of disappearing and substitution. The risk of disappearing is reflected, as reported by the INALI [9], by the small number of speakers, the geographical dispersion of native speakers, the prevalence of adult speakers, and the tendency to abandon transmission strategies of language to youngest generations. Additionally, due to the governmental policies on linguistic and cultural homogenization, native language´s speakers tend to adopt common languages, often as a result of migration processes [10]. As a consequence, speakers combine multiple meanings of other languages with their native language, resulting in the emergence of new and unpredictable linguistic properties. Based on data provided by the INALI [9], in Mexico 64 native linguistic variants present an extreme risk of disappearing; 43 have a high risk; 72 show a medium risk; and 185 present a nonimmediate risk.

Table 1 shows the risk of disappearing for the Mixe-Zoque linguistic family, formed by seven linguistic groups: Ayapaneco, Mixe, Oluteco, Popoluca de la Sierra, Sayula Popoluca, Texistepequeño, and Zoque. This chapter focuses on the study of Mixe linguistic group.

Due to its inherent complexity, emergent properties of Mixe linguistic group cannot be determined by traditional methods such as analytical models, but rather should be studied using simulation models, which in recent years has been recognized as an experimental tool in modern science. The aim of this chapter is to analyze the impact of idiolect mutations on the evolutionary dynamics of linguistic group Mixe in communities such as Camotlán,

Linguistic family	Linguistic group	Risk of disappearing
Mixe-Zoque	Ayapaneco	1
	Mixe	**4**
	Oluteco	1
	Popoluca de la Sierra	4
	Sayulteco	3
	Texistepequeño	1
	Zoque	4

1. Very high, 2. Act, 3. Medium, 4. Nonimmediate.

Table 1. Risk of disappearing of linguistic groups of Mixe-Zoque family [9].

San Sebastián, Puxmetacán, and Coatlán geographically located in Oaxaca, Mexico. We believe that a better understanding on the evolutionary dynamics of linguistic groups through agent-based simulation models can provide the main guidelines for establishing effective public policies to reduce the risk of disappearing native languages in Mexico.

This chapter is divided into five main sections. First, a conceptual model of Mixe linguistic group as a complex adaptive system is developed. Second, an agent-based simulation model is implemented using NetLogo software. Third, the evolutionary dynamics of Mixe linguistic group is analyzed as function of the mutation rate of native speaker´s idiolects. Finally, the concluding remarks are drawn.

2. Mixe language as a complex adaptive system

The concept of complex adaptive systems (CAS) was first introduced by Walter Buckley in 1967 and refers to systems that are composed by multiple interrelated fundamental elements interacting in a nonlinear way whose structure is based on hierarchical levels. The interrelated elements are complex in nature and are characterized by significant internal properties that are highlighted as being part of a total system [11]. In the study of CAS, it is interesting to know their emergent properties that arise at a higher structural level as a result of interactions among elements at a lower structural level. It is also of interest to know the fitness landscape that depends on the state variables of CAS, which change over time.

To carry out the study of emergent properties, the synthetic microanalysis and simulation are mainly used. Through the development of simulation models, it is possible to understand the evolution of CAS. In this section, the conceptual model of the linguistic group Mixe is developed based on CAS approach. In Section 2, the agent-based simulation model is implemented using NetLogo software.

2.1. Modeling Mixe language as a complex adaptive system

Mixe area is geographically located in Oaxaca, Mexico, and politically constituted by 19 municipalities and 106 Mixe agencies [12]. Mixe agencies are grouped in three geographical zones: the uptown, the middle, and the lower (see **Figure 2**).

In this chapter, we study two agencies located on the middle zone, Camotlán and San Sebastián, and three agencies located on the lower zone, Puxmetacán, Mazatlan, and Coatlán.

Based on the systemic composition from the synthetic microanalysis suggested by Auyang [13], the Mixe linguistic group is conceptualized as a CAS, presenting the following characteristics:

- Multiple key components—Native speakers of Mixe language, near to 100,000 [12], have oral tradition that emerges from the sociocultural interactions among the natives.
- Different structural levels—At microlevel, Mixe language is constituted by idiolects of individual native speakers, whereas at macrolevel, Mixe language is constituted by the communal language. In the case of Camotlán, San Sebastián, Puxmetacán, Mazatlan, and

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Coatlán agencies, the evolution of Mixe language is observed at macrolevel. It is a result of micromechanisms that govern sociocultural interactions among natives. In this direction, Mixe language is spoken in different ways from one agency to other, creating new language variants. Additionally, in agencies adults prefer Mixe language to communicate [12].

- Intrinsic diversity among its key components—Individual idiolects are products of the exposure of speakers to Mixe language [14] and the experiences within a socioeconomic, cultural, and environmental context. Over the last 450 years, Mixe people have developed a struggle of resistance and defence of their freedom and autonomy to decide themselves about their territory, the natural resources, economy, religion, and cultural organization [12].
- Functional dynamics—Mixe language is an open system that exchanges information with the complex environment that surrounds it. In order to survive, it is necessary that Mixe language adapt itself to new environmental conditions, adjusting its functional units through modification and selections of cultural memes.
- The impact of the social structure—Linguistic interactions among natives of Mixe agencies are not random but rather are limited by social networks, both internally and externally. As Ref. [15] explains, the social structure and sociocultural interactions among speakers have a crucial affect on the process of language evolution. In the case of Mixe agencies, the social structure is based on communities and the principal of them is the family. Thus, Mixe communities are large families composed by smaller families. It is important to note that the communal authority supports the power all times in the general assembly and is constituted by elderly people [12].

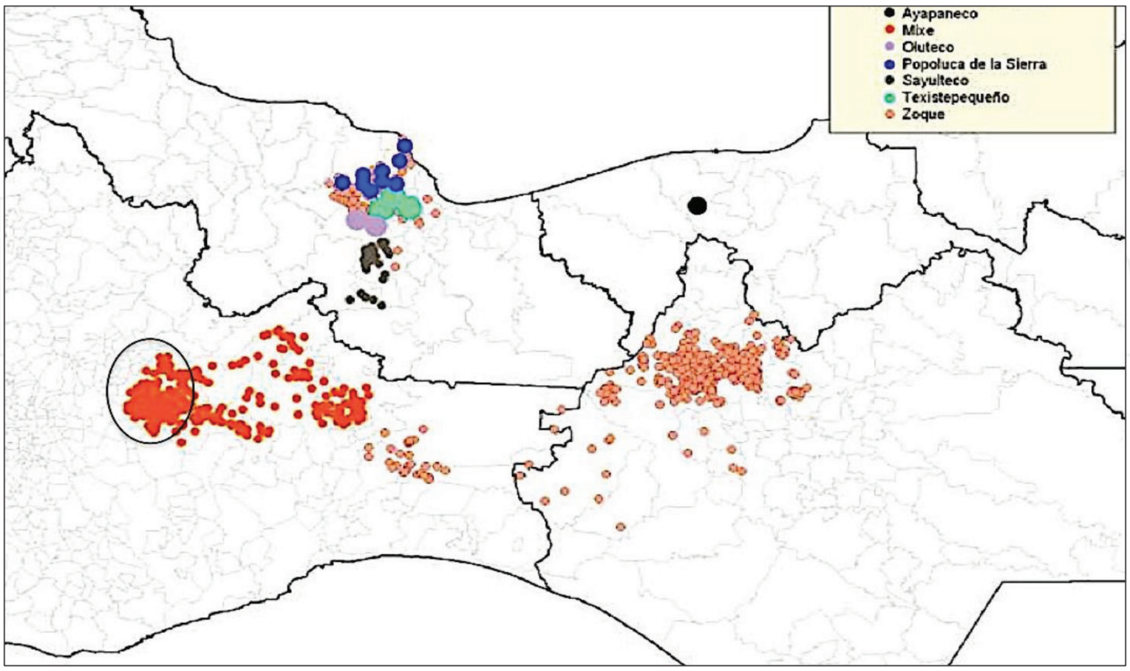

Figure 2. Geographical location of communities whose native linguistic groups belong to the native linguistic family Mixe-Zoque.

2.2. The evolution process of Mixe language

As Ref. [16] notes, the evolution of a language is part of the evolution of interactions among speakers and their communities. Based on Darwin evolution theory, the evolutionary dynamic of Mixe language can be explained by means of two main processes: replication and selection.

On the one hand, the replication process generates descent idiolects with modification. The language dynamic in this case can be understood as a change in the language due to replication of idiolects. In case of cultural transmission, the replication process includes changes in language [17]. As Ref. [18] explains, changes in languages are given from cultural memes such as thoughts, ideas, and ideologies that are learned and passed from person to person. Thus, during cultural changes, people are the transmitters of such changes [19].

On the other hand, speakers are engaged in a sociocultural context based on both the message to be transmitted and the social structure of their own community. Thus, speakers of Mixe language make a selection of those linguistic variants replicated. From the evolutionary point of view, the new variants of Mixe language that achieve a high replication frequency spread across communities, creating new variants. In the next section, an agent-based simulation model is implemented considering the conceptual model of Mixe language as a CAS to analyze the conditions under which new language variants emerge.

3. An agent-based simulation model of Mixe language

The goal of an agent-based modeling and simulation is to create computational agents that interact intelligently with their artificial environment. According to Ref. [20], computational agents are typically characterized as follows:

- Autonomy—Agents have direct control of their own actions and internal state.
- Social skill—Agents interact with other agents through a computer language.
- Reaction—Agents are able to perceive the complex environment and respond to it. The environment can be physical, virtual or simulated, and include other agents.
- Proactivity—Because agents react to complex environments, they must take goal-oriented initiatives.

Agents also have a degree of intentionality, thus the environment must be interpreted in terms of a metaphorical vocabulary of beliefs, desires, motives, and emotions, which are applied more in the description of people. Some of the attributes of interest in the modeling of agents are, for instance, knowledge and beliefs, inferences, social models, goals, planning, language, and emotions.

A typical agent-based simulation model contains the following four elements [21]:

- Agents, their attributes, and the complex environment.
- Relationships among agents and the interaction methods.

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- A network for connectivity that defines how and with whom agents interact.
- Agents live and interact with their own environment and with other agents.

The software used to program agents has its origins in the areas of artificial intelligence, in the subfield of distributed artificial agents [22, 23], whose aims of study are the properties of agents and the networks of interactions. Although there is a great variety of software for implementing agent-based simulation models, NetLogo™ is the most preferred by modelers [24]. NetLogo™ simulation software is widely used by the simulation model developer community. It is an open programming language that considers a baseline grid. Agents are represented by squares, and the state of each agent is updated depending on the state of its neighbors when there are interactions among them. The interesting thing about agent-based simulation modeling using NetLogo™ is that it is possible to observe the patterns which emerge from the interactions among agents without the existence of a centralize control.

3.1. An agent-based simulation model of Mixe language

At individual level, it is assumed that native speakers of Mixe language are able to generate their idiolects from their own experience within a sociocultural context. In this case, Mixe speakers with their own idiolects are modeled as agents, whereas at community level, Mixe language is considered a communal emergent property that arise from the complex dynamic interactions among idiolects of native speakers, as suggested by Baicchi [8]. The interface of the agent-based simulation model using NetLogo™ consists of simulation parameter´s controls and a grid of 35 × 35 squares. Each square represents virtually an agent with its own idiolect that is randomly assigned at the beginning of the simulation model execution. The minimum number of idiolects assigned at the beginning is 255. Each idiolect is characterized by the following parameters: number of attributes, the mutation rate, the influence factor, and the threshold of intelligibility. Indeed, in the latter case, it is considered a linguistic property through which two different idiolects can understand each other without having studied or learned previously the other. We also assumed that agents interact a defined number of times within a geographical delimited area.

4. Analyzing the evolutionary dynamic of Mixe language

We designed two simulation scenarios on which the simulation parameter´s values are varied (see **Table 2**) to analyze the evolutionary dynamic of Mixe language as a function of the mutation rate of idiolects in communities such as Camotlán, San Sebastián, Puxmetacán Mazatlan, and Coatlán. The simulation time was fixed to 50 discrete steps.

Table 3 shows the results of a field study reported by Wurn et al. [25] about the values for linguistic intelligibility of Mixe languages in Camotlán, San Sebastian, Puxmetacán, Mazatlan, and Coatlán.

4.1. Analysis of the evolutionary dynamics of Mixe language in Camotlán

Figure 3(a) illustrates the simulation results for scenario 1. The simulation model initially considers about 255 diverse idiolects assigned randomly among the agents. As agents start to interact socially with other agents considering a mutation rate equal to zero, the number of idiolects decreases until the prevalence of a few. As seen in **Figure 3(b)**, simulation scenario 2, the simulation model initially considers around 330 diverse idiolects assigned randomly

Parameter values	Scenario 1	Scenario 2
Number of interactions	6	6
Mutation rate	0%	100%
Maximum distance among speakers	3	3
Threshold of influence factor	50%	50%
Number of speakers or agents	1225	1225

Table 2. Parameter values and simulation scenarios.

Mixe community	Linguistic intelligibility value
Camotlán	96
San Sebastián	94
Puxmetacán	86
Mazatlán	90
Coatlán	100

Table 3. Values of linguistic intelligibility in Mixe communities.

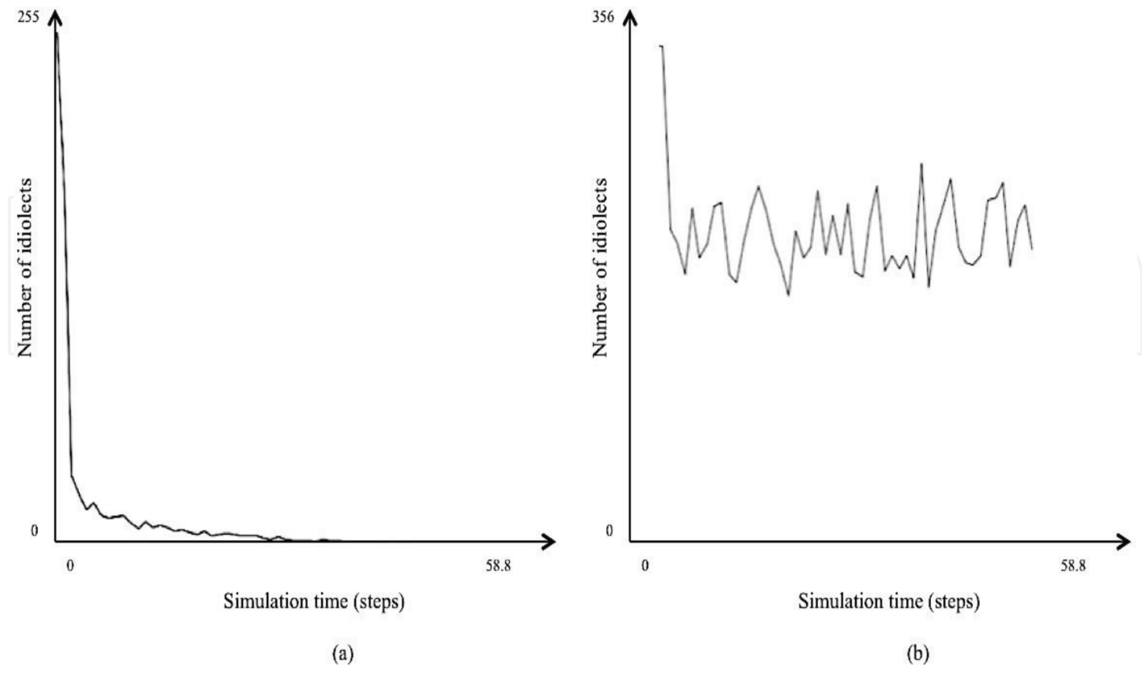

Figure 3. Evolutionary dynamics of Mixe language in Camotlán, (a) mutation rate equal to 0%, (b) mutation rate equal to 100%.

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among the agents. As agents start to interact socially considering a mutation rate equal to 100, the number of idiolects decreases slowly and remains oscillating around 170.

4.2. Analysis of the evolutionary dynamics of Mixe language in San Sebastián

Figure 4(a) illustrates the results of simulation scenario 1 for San Sebastian community. The simulation model initially considered about 300 different idiolects. As agents start to interact socially with a mutation rate in their idiolects equal to zero, the number of idiolects decreases rapidly. As seen in **Figure 4(b)**, the case of simulation scenario 2, the simulation model initially considered around 330 different idiolects. As agents start to interact socially with a mutation rate in their idiolects equal to 100, the number of idiolects decreases slowly and remains oscillating around 180, reaching peaks at values of 300.

4.3. Analysis of the evolutionary dynamics of Mixe language in Puxmetacán

Figure 5(a) illustrates the results of simulation scenario 1 for Puxmetacán community. The simulation model initially considered about 300 different idiolects. As agents start to interact socially with a mutation rate in their idiolects equal to zero, the number of idiolects decreases rapidly. After twenty steps in the simulation model very few idiolects remain. As seen in **Figure 5(b)**, the case of simulation scenario 2, the simulation model initially considered around 300 different idiolects. As agents start to interact socially with a mutation rate in their idiolects equal to 100, the number of idiolects decreases slowly and remains oscillating around 210, reaching peaks at values of 260.

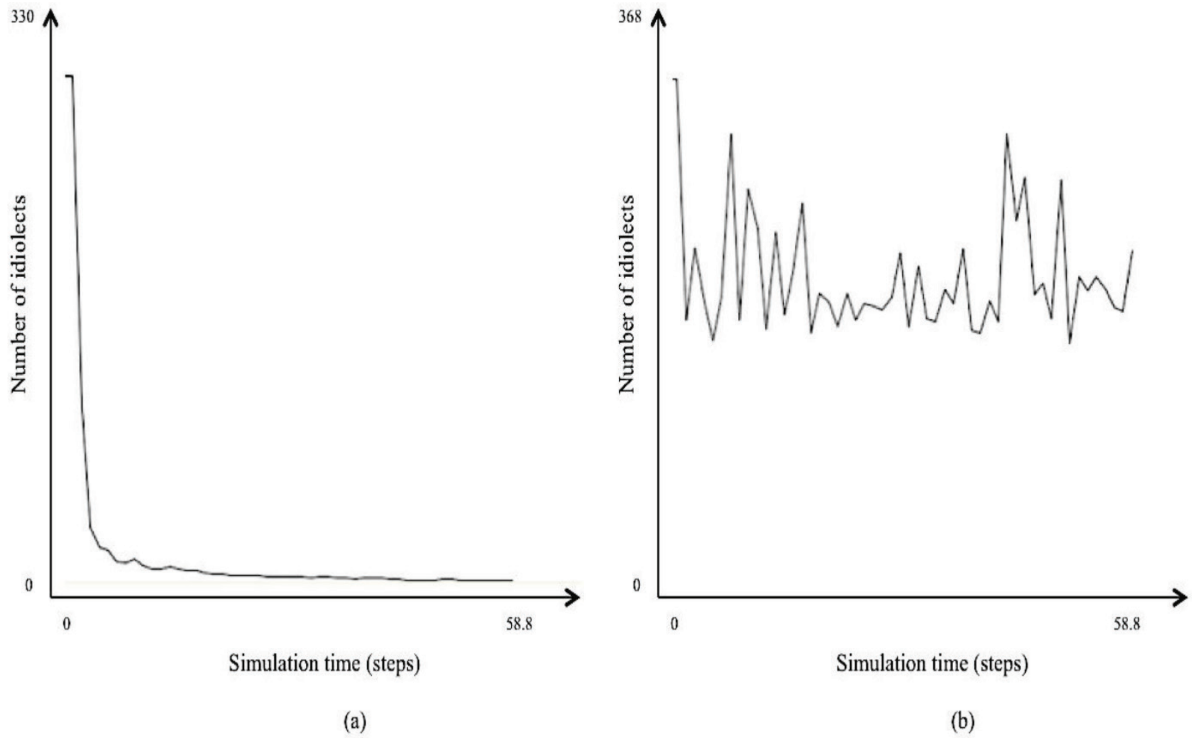

Figure 4. Evolutionary dynamic of Mixe language in San Sebastián, (a) mutation rate equal to 0%, (b) mutation rate equal to 100%.

4.4. Analysis of the evolutionary dynamics of Mixe language in Mazatlan

Figure 6(a) illustrates the results of simulation scenario 1 for Mazatlan community. The simulation model initially considered about 300 different idiolects. As agents start to interact socially with a mutation rate in their idiolects zero, the number of idiolects decreases rapidly.

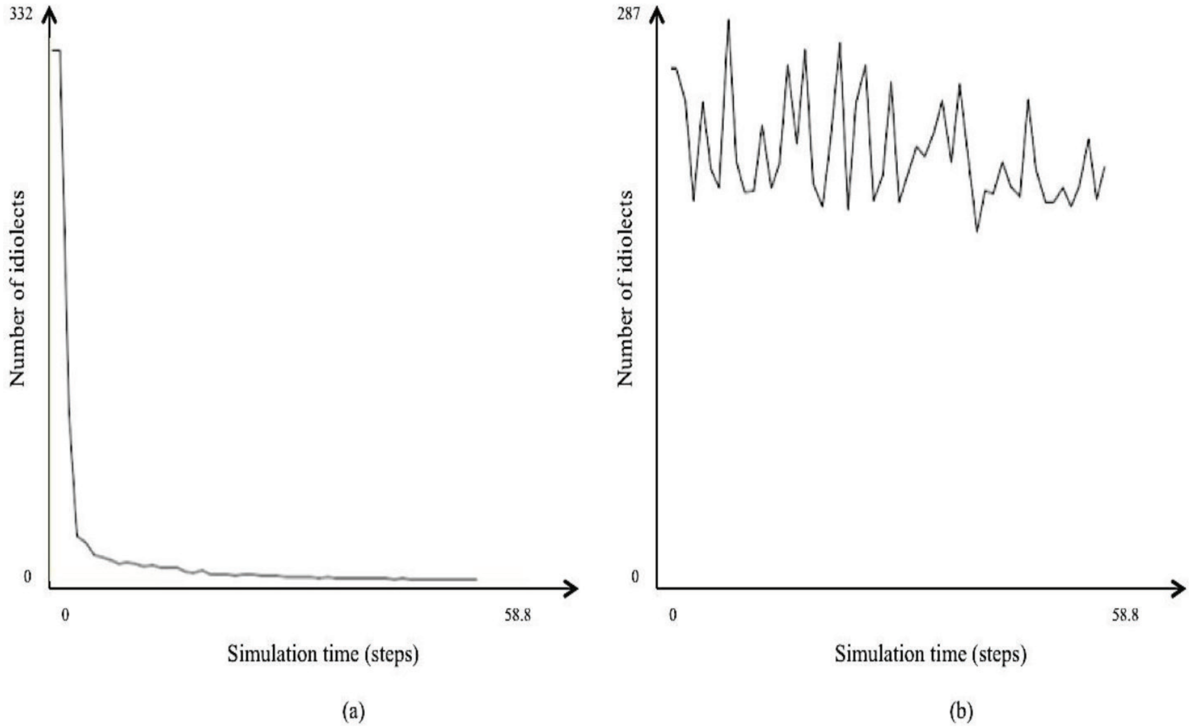

Figure 5. Evolutionary dynamic of Mixe language in Puxmetacán, (a) mutation rate equal to 0%, (b) mutation rate equal to 100%.

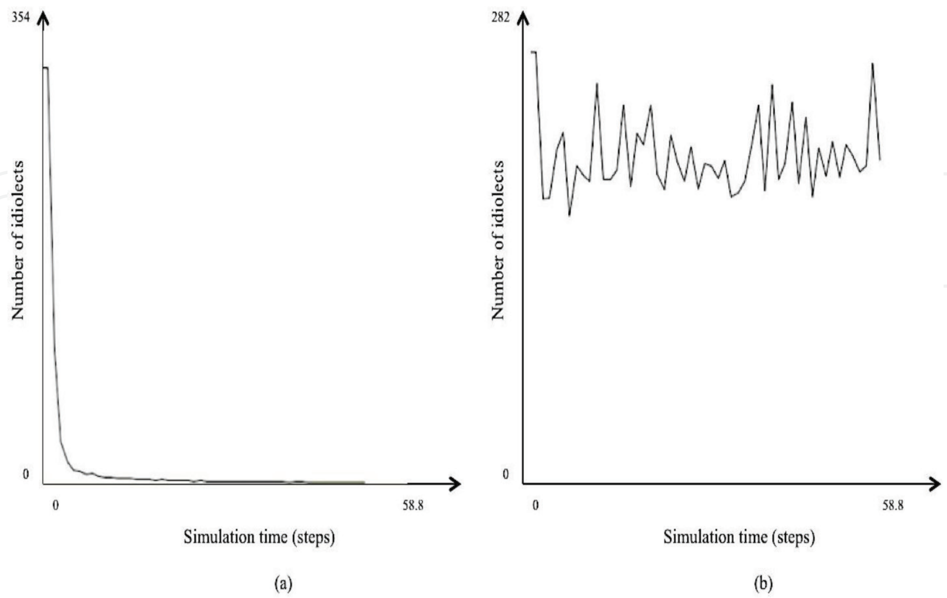

Figure 6. Evolutionary dynamic of Mixe language in Mazatlan, (a) mutation rate equal to 0%, (b) mutation rate equal to 100%.

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After fifteen simulation steps, a few idiolects survive. As seen in **Figure 6(b)**, the case of simulation scenario 2, the simulation model initially considered around 260 different idiolects. As agents start to interact socially with a mutation rate in their idiolects equal to 100, the number of idiolects decreases slowly and remains oscillating around 170, reaching peaks at values of 260.

4.5. Analysis of the evolutionary dynamics of Mixe language in Coatlán

Figure 7(a) illustrates the results of simulation scenario 1 for Coatlán community. The simulation model initially considered about 300 different idiolects. As agents start to interact socially with a mutation rate in their idiolects zero, the number of idiolects decreases rapidly. As seen in **Figure 7(b)**, the case of simulation scenario 2, the simulation model initially considered around 300 different idiolects. As agents start to interact socially with a mutation rate in their idiolects equal to 100, the number of idiolects decreases slowly and remains oscillating around 200, reaching peaks at values of 250.

5. Concluding remarks

From the simulation model results, we observed that when the mutation rate in idiolects is equal to zero, through the interactions among speakers, the language becomes homogeneous, that means a very small number of idiolects survive so the Mixe native language remains with minimal linguistic variations. On the contrary, when the rate of mutation in the idiolects of speakers is equal to 100, a large number of idiolects remain active. In consequence, a large

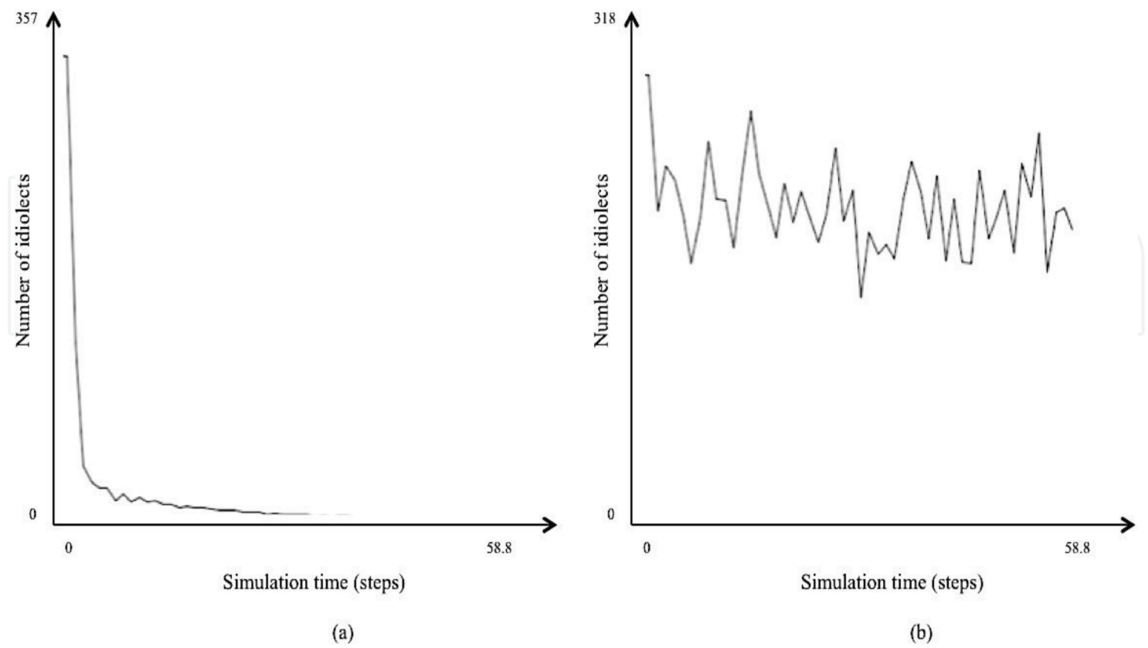

Figure 7. Evolutionary dynamic of Mixe language in Coatlán, (a) mutation rate equal to 0%, (b) mutation rate equal to 100%.

number of language variants are generated and the risk of disappearing for the Mixe language increases. The simulation results in both cases are independently of the initial number of idiolects that are randomly assigned to speakers at the beginning of the simulation execution. That means, in the case of mutation rate equal to zero, the number of idiolects decreases fast and tends to be zero in a minimum time, while in the case of mutation rate equal to 100, the number of idiolects decreases slowly and remains oscillating along a certain number, but it never tends to be zero. A similar situation is observed in the case of the variation in the next three simulation parameters: the number of interactions among agents, the number, and the distance of speakers. To lower/higher value of these parameters at a mutation rate equal to zero, correspond to a low decrease in the number of idiolects, but along time the number of idiolects tend to be zero. While to lower/higher value of interactions, number and the distance of speakers at a mutation rate equal to 100 correspond a large number of idiolects that remain active whose value oscillates but never decreases to zero. In conclusion, the influence of simulation parameters such as the number of interactions, the number, and the distance of speakers on the evolutionary dynamics of Mixe language is just in terms of time. The importance of native languages in Mexico is based on the fundamental role they play in the society and culture, as they provide the central means through which cultural knowledge is transmitted. Therefore, the public policies of revitalization of native languages such as Mixe should be focused primarily on increasing the number of speakers through effective strategies for the transmission to youngest generations, and second, in improving living conditions of native speakers in their own territories in order to reduce the rate of migration which encourages to speakers for the adoption of common languages generating language variants through the combination of multiple meanings of other languages with Mixe.

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